blacks fought by Stanley. The Central Section of the Paris Geographical Society has decided to give to MM. Brazza and Ballay the great gold medal for 1879. Some members proposed to give it to Nordenskjöld, but the prolongation of his voyage, owing to his detention in Behring's Straits, was considered sufficient reason to adjourn Nordenskjöld's claims to 1880.

MANY proposals have been made for a new initial meridian to be adopted by all nations, but no satisfactory solution has yet been reached. The present state of things is very confusing, with nearly as many different initial meridians as there are civilised countries. In *L'Exploration* M. de Beaumont proposes the adoption of a zero passing through Behring's Straits and down the Pacific, its antemeridian passing through the centre of Europe and Africa; but, indeed, any universally-adopted zero would be better than the present confusion.

THE capitalists of Liverpool and Manchester, finding so many of the old markets shut against their enterprise, propose making a railway 500 miles long, from Zanzibar to the south end of Victoria Nyanza, to develop the trade of Central Africa. In the speeches on the subject at Manchester great ignorance was shown of the geography and hydrography of the region in question, and if only a desire to develop the resources of Africa is at the bottom of the movement, it is quite unnecessary to spend a million of money on a railway. With the magnificent water-way explored by Stanley and other travellers, and with the help of either Indian or tamed African elephants, the resources of Central Africa could be quite adequately developed for many years to come.

IN the January number of Petermann's *Mittheilungen* Dr. Gerhard Rohlfs gives the results of his search, during his last journey in the Libyan Desert, for the supposed empty river-bed of the "Bihâr-Bilâ-mâ." He discusses the chief references to this supposed extinct river, and concludes from his researches that there is no warrant for placing its dried-up bed on our maps. The same number contains a fine map of the region about the sources of the Oxus, with short explanatory text by Dr. Behm, and a map of North Siberia, showing Nordenskjöld's track from the Yenessei to the Lena. Accompanying the latter are German translations of the letters of various members of the expedition.

A CONTRACT has been concluded by M. Sibiriakoff, of Irkutsk, in Siberia, with the firm of Kockum, whereby the latter are to build him a steamer of 350 tons burden, for the purpose of going to the assistance of the *Vega*. It is expected that the steamer will be ready soon enough to start, fully equipped with provisions, in time to reach Behring's Straits, by way of the Suez Canal, next August, in order to assist Prof. Nordenskjöld and his companions. The vessel will afterwards trade to the Lena, and, if possible, even to the Yenessei.

AN Italian traveller, Manzoni, made a journey of some importance in Yemen, Arabia, in 1877, the results of which appeared in the *Exploratore*. In June last Manzoni commenced a second journey from Aden northwards to Asir and eastwards to Hadramaut. After visiting several places of interest he arrived in Sana, where, according to last reports, we learn from Dr. Behm's summary, he was ill. This exploration is supported by the Italian *Cosmos*.

THE last number of the *Isvestia* of the Russian Geographical Society contains an important paper by M. Maieff, giving an account of his journey last summer to South Bokhara. M. Maieff describes the various *beckdoms* or subdivisions of Bokhara, their productions, trade, and people, their chief physical features and hydrography. He concludes by some important information on the various routes from Guzar to the Amu Daria and Afghanistan.

A LETTER received from M. Oshanin, from Turkestan, announces that he has just returned from his great journey to Karataghin. He has discovered a very fine glacier, which he has called by the name of the late Fedchenko. This is the third locality bearing the name of the traveller: M. Ujfalvy has called the Lake Kutban-kul "Lake Fedchenko," and M. Maieff has given the same name to one of the peaks of Ghissar.

THE GEOLOGICAL HISTORY OF THE COLORADO RIVER AND PLATEAUS[1]

FOR convenience of geological discussion, Prof. Powell has divided that belt of country which lies between Denver and the Pacific, and between the 34th and 43rd parallels, into provinces, each of which, so far as known, possesses structural and topographical features which distinguish it from the others. The easternmost he has named the Park Province. It is characterised by lofty mountain ranges, consisting of granitoid and metamorphic rocks pushed upward and protruded through sedimentary strata, the latter being turned upwards upon the flanks of the ranges and their edges truncated by erosion. The generalised transverse section, on the assumption that the sedimentaries, prior to uplifting, were continuous across the mountains, is that of a broad and extensive anticlinal, sometimes profoundly-faulted parallel to the trend, the sedimentary strata which may once have extended across being removed by erosion. The intervening valleys still retain the entire sedimentary series. This form of mountain structure, with its resulting topographical features, gradually passes, as we go westward, into another type, arising from the decreasing frequency of the greater displacements or differential vertical movements of the earth's surface; but most frequently the dislocation is a combined monoclinal and a fault, or series of faults, with all shades of relative emphasis. The small departure from horizontality amid great general displacement is a strong trait, and justifies the name which has been applied to it by all observers with one accord—the PLATEAU COUNTRY.

West of this province lies a third one—the Great Basin. It is characterised by short, jagged mountain ridges, separated by goodly intervals of barren plains. These ridges are usually produced by the up-lifting of the strata along one side of a fault. Sometimes the faults are multiple, that is, consist of a series of parallel faults, the intervening blocks being careened in the same manner and in the same direction. This repetitive faulting is of very common occurrence. Other modifications, and even different types of structure, are presented; but there is throughout the Great Basin a striking predominance of monoclinal ridges, in which one side of a range slopes with the dip of the strata, and the other side slopes across their upturned edges. The forms impressed upon these masses by erosion are rugged, bristling, and sierra-like, and their peculiarities are aggravated by the fact that before these mountains were brought forth the platform of the country from which they arose had been plicated and the plications planed down by erosion. The Basin is the oldest western land of extensive area. Its final emergence was not later than Jurassic, and may have a still older date.

Between the Plateau and Park Provinces there is no definite boundary. Gradually as we proceed westward from the Parks of Colorado the valleys widen out and expand into a medley of terraces, bounded by cliffs, which stretch their tortuous courses across the land in every direction, yet not without system. The boundary separating the Plateau Province from the Great Basin, on the contrary, is abrupt. In many parts of its extent it seems almost possible to hurl a stone from one province to the

[1] By Capt. C. E. Dutton, U.S. Army, Assistant-Geologist U.S. Survey o the Rocky Mountain Region, under Prof. J. W. Powell, in charge.

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other. Still there is a border country where the plateaux take on a type of structure which suggests the Basin type, though never to be confounded with it. Powell has given it the name of Kaibab structure, and through it the Grand Cañon of the Colorado cuts transversely. This structure extends northward from the Grand Cañon more than 250 miles, reaching within 100 miles of the Uintas, or even nearer than that. Between the great faults tabular masses have been uplifted to the average altitude of 11,000 feet, with grand valleys between them.

To the eastward of these high plateaus is spread out a wonderful region. Standing upon the eastern verge of any one of these, where the altitude is nearly 11,500 feet, the eye ranges over a vast expanse of nearly level terraces bounded by cliffs of strange aspect (Fig. 1). They wind about in all directions, here throwing out a great promontory, there receding in a deep bay, but continuing on and on until they sink below the horizon, or swing behind some loftier mass, or fade out in the distant haze. Very wonderful, too, is the sculpture of these majestic walls.

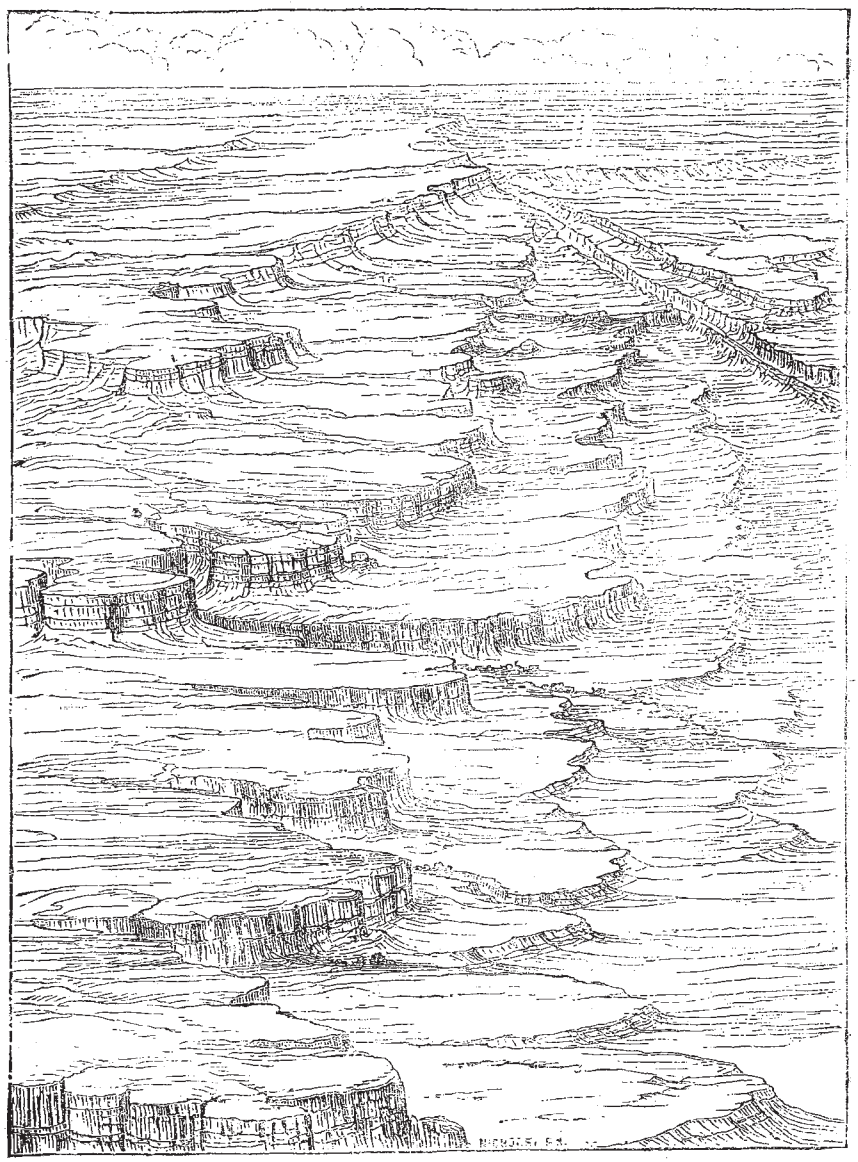

FIG. 1.—Bird's-eye view of Cliffs of Erosion, showing the Shin-ar-Ump Cliffs, Vermilion Cliffs, and Gray Cliffs, in order from Right to Left.

Panels, pilasters, niches, alcoves, buttresses, needing not the slightest assistance from the imagination to point the resemblance—grotesque colossal forms neatly carved out of solid rock, endless repetitions of shapes, which pique the fancy to find analogies, are presented to us on every hand, and fill us with wonder as we pass. But of all the characters of this unparalleled scenery, that which appeals most strongly to the eye is the colouring. The gentle tints of an eastern landscape, the rich blue of distant mountains, the green of summer vegetation, the subdued tints of hill-side and meadow—all are wanting, and in their place we behold belts of fierce, staring red, yellow, and toned white, which are intensified rather than alleviated by alternating belts of dark iron-gray. The Plateau Country is the land of cañons. Gorges, ravines, cañadas, are found in every high country, but cañons belong to the region of plateaus. Like every other river the Colorado has many tributaries, and in former times

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had many more than now; and every branch and every twig of a stream here runs in a cañon. The land is honey-combed with them. To cross it, except in certain specified ways, is a feat reserved exclusively to creatures endowed with wings. The region is a desert of the most formidable description. A few attenuated streams

FIG. 2.—Grand Cañon of the Colorado (6,200 feet deep).

meander through it, but usually in cañons of which the bottoms are somewhere between the earth's surface and centre. The springs will not average one to a thousand square miles. But in the High Plateaus, at levels above 7,500 feet, we find a moist climate, exuberant vegetation, and hundreds of sparkling streams.

During Cretaceous times, the Plateau Country was a marine area. After 4,000 feet of Cretaceous strata were

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deposited, a large portion, and perhaps the whole of this region became, for a time, land, and the uplifting was attended by considerable dislocation and flexing of the strata. In numerous localities the Cretaceous strata are seen to be denuded, and the lowest Tertiary beds lie across the bevelled edges. This uplifting took place after the deposition of a group of beds which in part, at least, are the equivalents of those which King and Hayden have named the Laramie Group. I accept the verdict of Marsh, Meek, King, and Powell, that these beds belong to the local Cretaceous series, and reject the decision of Hayden, that they are Tertiary. Thus the close of the Cretaceous is marked by a physical break separating it from the local Tertiary series by widely distributed unconformities.

After an unknown interval of denudation immediately following the close of the Cretaceous period the region was again submerged, and then began the deposition of that remarkable series of Eocene beds which form such a striking feature in the stratigraphy of the peripheral parts of the Plateau Country. Around the southern flanks of the Uintas their aggregate thickness exceeds 4,000 feet, but south-westward the upper members at length disappear, and seventy miles north of the Grand Cañon only the lower portion of the local Eocene (the Bitter Creek of Powell or Vermilion Creek of King) remain; indeed, in the latter locality no later beds than the Bitter Creek were deposited. The evidence is now conclusive that the Bitter Creek series stretched more than a hundred miles across the Plateau Country, covering, doubtless, its entire extent, while the middle and later Eocene covered smaller areas to the northward. Only marginal remnants of these huge deposits now remain. The heart of them has been eroded and swept away. Just at the commencement of the Tertiary periods the Plateau Country was covered with brackish water, having perhaps an analogy to the Baltic or Euxine, but after the accumulation of a few hundred feet of deposits the region became a vast inland lake. Its northern shore was along the base of the Uintas, which had then apparently gained their first elevation. Its north-western shore, by a coincidence which can hardly be accidental, lay along the identical boundary which now sharply separates the Plateau Country from the Great Basin, and the latter was one of the mainlands which furnished the sediments of the lake. From the angle where the Uintas join the Wasatch it is possible to trace this shore line more than 300 miles south-westward into Arizona with certainty, and to point out its principal bays and headlands, and even to locate the sites of some of the ancient river channels through which the lower Eocene sediments were brought down. The eastern, south-eastern, and southern margins, and the remainder of the south-western margin, remain to be determined by future exploration. At length, after one-third to one-half of the lacustrine beds had been laid down, there began a series of events which has developed the physical features of the Plateau Country, and which has pursued an unbroken course to the present time, and which even yet may not have culminated. Then began that uplifting which has raised the Plateau Country more than 13,000 feet on an average. Then, too, began a marvellous erosion which has cut down the mean level about one-half that amount, leaving the present mean altitude nearly 6,500 feet. At the inception of this process the lake began to dry up, the south-western portion now drained by the Lower Colorado being the first to emerge. Gradually through the succeeding periods the lake contracted its area, withdrawing northward to the Uinta Mountains, where, at the close of the Eocene, it disappeared.

We are now in a position to trace the origin, growth, and history of the Colorado River, if not from the beginning, at least from an epoch near its beginning. Its creation was not the event of one epoch, but a gradual process extending through several periods. The lower course, extending from the mouth of the Virgin to the Pacific, is the oldest portion, and makes its appearance in geological history a little before, but very near, the middle Eocene. Whether it existed before this epoch is not beyond doubt, but probably it did. But earlier than the Tertiary periods it cannot go; for it is certain that up to the close of Cretaceous times the ocean flowed over its track. When the Plateau Country was first isolated from the ocean it became a brackish Euxine, and may be presumed to have had a Hellespont somewhere. It soon after became an inland lake and must have had a St. Lawrence to keep its waters fresh. There can be little doubt that in the middle Eocene the outlet was the lower course of the Colorado. Whether the lake prior to that had some other outlet which it abandoned for this one is an open question, with the probabilities (on general principles) in favour of the negative. But the question is of no great importance.

The growth of the Colorado may be illustrated by considering what might happen to the St. Lawrence if the whole region of the Canadian lakes were uplifted two thousand feet. In no great length of time Ontario would be drained by the St. Lawrence, lowering its channel, and that river would become one with the Niagara. The same process would be repeated at Erie, Huron, and Superior, the lakes vanishing and leaving only a great river with many branches. Such was the origin of the Colorado; first a Hellespont, then a St. Lawrence, then a common but rather large river heading in the interior of a continent. Its principal branch, the Green River, cuts through the Uinta mountains by the Flaming Gorge and Cañon of Lodore. A second lake, apparently coeval with the one we have just discussed, lay to the north of that range and poured its waters through these gateways into the southern lake. What other bodies of fresh water may have been connected with either of these it is impossible to say at present.

At the epoch when the desiccation was completed it is not probable that the cañons had any existence, for the indications are that the elevation of the country at the commencement of the Miocene period was not great. Conditions favourable to cañon cutting are highly exceptional, and there is no evidence that this exceptional combination of conditions existed at that time, while there is much evidence that it did not. That the conditions, however, were favourable to a rapid rate of erosion is highly probable. But the forms which it would produce might be more nearly analogous to those which may be observed in eastern Ohio and western Pennsylvania. That the climate was moist and sub-tropical is rendered probable by the vegetable remains found in the surrounding regions, and it is only rational to suppose that such a climate in a moderately elevated region would yield such results as may be seen in countries similarly conditioned. Whether the valleys were broad or narrow, abruptly walled or gently sloped, matters little. It is almost certain that they were not deep. The great cañons which we now see had not even been commenced, although they were foreshadowed, and the train of events which was to produce them at a later period had started into activity.

The history of the Colorado and its drainage system during Miocene time must be spoken of only in general terms. In truth during this great age there is no evidence of the occurrence of any critical event aside from the general process of uplifting and erosion which affected the region as a whole. The vast erosion of this region has swept away so much of its mass that most of the evidence as to the details has vanished with its rocks. But the more important features of the work, its general plan in outline, have left well-marked traces and these can be unravelled. It was a period of slow uplifting, reaching a great amount in the aggregate, and it was also

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a period of stupendous erosion. The uplifting however was unequal. The comparatively even floor of the old lake was deformed by broad gentle swells rising a little higher than the general platform. In consequence of their greater altitude these upswellings at once became the objects of special attention from the denuding agents and were wasted more rapidly than lower regions around them. Here were formed centres or short axes from which erosion proceeded radially outwards, and the strata, rising very gently towards them from all directions, were bevelled off. As the erosion progressed so also did the uplifting of these local centres or axes, thus maintaining the maximum erosion at the same localities. It is a most significant fact that the brunt of erosion is directed against the edges of the strata and not against their surfaces, provided the stratification is but little disturbed. Usually such an uplift will have one diameter longer than another; and we may call the greater the major-axis. The strata dissolve away in all directions by the waste of their edges, and after the lapse of long periods the newest or uppermost strata will be found encircling the centre of erosion at a great distance—the next group below will encircle it a little nearer, and so on.

This has been the history of each of the sub-divisions of the Plateau Country. Upon the western and northern sides of the Colorado five of these centres are now easily discerned. By far the largest and probably the oldest is around the Grand Cañon. All these had their inception in Miocene time, though the one around the Grand Cañon may go back into the upper Eocene. The district known as the San Rafael Swell is by far the best suited for study.

If we stand upon the eastern verge of the Wasatch Plateau and look eastward we shall behold one of those sublime spectacles which fill even the calmest observer with awe and amazement. From an altitude of more than 11,000 feet the eye can sweep a semicircle with a radius of nearly seventy miles. It is not the wonder inspired by great mountains, for only two or three peaks of the Henry Mountains are well in view, and these with their noble alpine forms seem as strangely out of place as Westminster Abbey would be among the ruins of Thebes. Nor is it the broad expanse of cheerful plains stretching their mottled surfaces beyond the visible horizon. It is a picture of desolation and decay; of a land dead and rotten with dissolution apparent all over its face. It consists of a series of terraces all inclining upwards towards the east. We stand upon the lower Tertiary rocks and right beneath our feet is a precipice leaping down across the edges of the level strata upon a terrace 1,200 feet below. This cliff stretches away northward gradually swinging eastward, and finally southward, describing a rude semicircle around a centre about forty miles to the eastward. At the foot of this cliff is a terrace about six miles wide of upper Cretaceous beds inclining upwards towards the east very slightly, and at that distance it is cut off by a second great cliff plunging down 1,800 feet upon middle Cretaceous beds. This second cliff describes a smaller semicircle concentric with the first. From the foot of the second cliff the strata again rise through a width of about ten miles and are cut off again by a third series of cliffs as before. There are five of these concentric lines of cliffs. In the centre there is an elliptical area forty miles long and twelve to twenty wide, its major axis being north and south, which is as completely girt about by rocky walls as the valley of Rasselas, but such walls as Dr. Johnson never dreamed of. We have given it the name of the Red Amphitheatre. Yet, if we look back to Eocene time, we shall find that the whole stratigraphic series, up to the Eocene inclusive, covered this amphitheatre. Nearly 10,000 feet have now gone, and the floor is near, or quite, at the summit of the Carboniferous rocks. At present the Amphitheatre is drained by two streams which cut across it and find their way, one into the Green, the other into the Colorado, below the junction of the Grand.

Still more vast is the erosion which has taken place from the vicinity of the Grand Cañon. Here the Carboniferous strata form now the floor of the country, though a few patches of Trias still remain in the vicinity of the river. But the main body of the Triassic rocks stands now fifty miles north of the river, and beyond them, in a series of great terraces, rise the Jurassic, Cretaceous, and Tertiary formations—the latter capped with immense bodies of volcanic rock. The greater part of the erosion was accomplished in Miocene time.

It will be seen that these local uplifts are important in determining the subdivisions of the area and the distribution of the maxima and minima of degradation. We may see here a correspondence which is worthy of close attention. Those areas which have been uplifted most have been most denuded. I have asked myself a hundred times whether we might not turn this statement round, and say that those regions which have suffered the greatest amount of denudation have been elevated most, thereby assuming the removal of the strata as a cause and the uplifting as the effect; whether the removal of such a mighty load as ten thousand feet of strata from an area of ten thousand square miles may not have disturbed the earth's equilibrium of figure, and that the earth, behaving as a *quasi*-plastic body, has reasserted its equilibrium by making good a great part of the loss by drawing upon its whole mass beneath. Few geologists question that great masses of sedimentary deposits displace the earth beneath them and subside. Surely the inverse aspect of the problem is *à priori* equally palpable. That some such process as this has operated in the Plateau Country looks at least very plausible, and, if there could be found independent reasons for believing in its adequacy, the facts certainly bear it out. Yet its application is not without some difficulties, and the explanation is not quite complete. Granting the principle, it will be still difficult to explain how these local uplifts were inaugurated; and we can only refer them to the agency of that mysterious plutonic force which seems to have been always at work, and whose operations constitute the darkest and most momentous problem of dynamical geology. On the whole it seems to me that we are almost driven to appeal to this mysterious agency to at least inaugurate, and perhaps in part to perpetuate, the upward movement, but that we must also recognise the co-operation of that tendency which indubitably exists within the earth to maintain the statical equilibrium of its levels. The only question is, whether that tendency is merely potential or becomes partly kinetic; and this again turns upon the rigidity of the earth. But it is easy to believe that, where the masses involved are so vast as those which have been stripped from the San Rafael Swell, and from the Kaibabs around the Grand Cañon, the rigidity of the earth may become a vanishing quantity.

Let us turn now to a law which forms a most important link in the chain of discussion—a law without a thorough comprehension of which the structural geologist in the Plateau Country would see very little except Sphinxes, but one which, when he has fully saturated his mind with it, will enable him to translate many mysteries. This law may be called the persistence of rivers. It is a very simple one, but its uses are wonderful; indeed those who have found it so invaluable in the Plateau Country often wonder why so little use has been made of it elsewhere. If the study of this region should accomplish nothing more than drawing this principle from its modest retirement and installing it in its rightful place in the logic of geology it will still have accomplished a great result. But the law has its limits, which we cannot overstep with safety.

Of all the changing features of a continent the least changeful are its great rivers. Undoubtedly rivers have

perished and undoubtedly they have shifted parts of their courses somewhat; but on the whole their tenacity of life is wonderful, and the obstinacy with which they sometimes maintain their positions is in powerful contrast with the instability of other topographical features. This characteristic, however, fails at low levels. A river near its mouth may often change its course; but where the country is high enough to enable it once to fasten its grip it will hold it, despite all the changes to which the surface of a continent is ordinarily subject throughout the term of its secular existence. Its stability and persistence will depend usually upon its altitude, or what amounts to the same thing, upon the rapidity of its slope. When that is small we may look for signs of inconstancy. Other conditions might be formulated which could affect it or modify it; but on the whole the fact remains that rivers have a remarkable power of maintaining their positions. It would be difficult to point out an instance where a great river has ever existed under conditions more favourable to longevity and stability of position than those of the Colorado and its principal tributaries. Since the epoch when it commenced to flow it has been situated in a rising area. Its springs and rills have been among the mountains and its slope has throughout its career been continuously though slightly increasing. The relations of its tributaries have in this respect been the same, and indeed the river and its tributaries have been a system and not merely an aggregate, the latter dependent upon and perfectly responsive to the physical conditions of the former. And now we come to the point. The Colorado and its tributaries run to-day just where they ran in the Eocene period. Since that time mountains have risen across their tracks, whose present summits mark less than half their total uplifts; the river has cleft them down to their foundations. The Green River, passing the Pacific Railway, enters the Uintas by the Flaming Gorge, and after reaching the heart of this chain, turns eastward parallel to its axis for thirty miles, and then southward, cutting its way out by the splendid cañon of Lodore. Then following westward along the southern base of the range for five miles, a strange caprice seizes it. Not satisfied with the terrible gash it has inflicted upon this noble chain, it darts at it viciously once more, and entering it, cuts a great horse-shoe cañon more than 2,700 feet deep, and then emerging, goes on its way. Thenceforward, through a tortuous course of more than 300 miles down stream the strata slowly rise—the river almost constantly running against the gentle dip of the beds, cutting through one after another, until its channel is sunk deep in the carboniferous. Further down, near the head of the Marble Cañon, the Kaibab rose up to contest its passage, and a chasm more than 6,200 feet in depth bears witness to the result. It is needless to multiply instances. The entire province is a vast category of instances of drainage channels running counter to the structural slopes of the country. I am unable to recall a single tributary to the right bank of the Colorado which does not somewhere, and generally throughout the greater part of its course, run against the dips. The northern tributaries of the Grand Cañon have their entire courses thus related. If we were to take the sums of the lengths of the river and its right hand affluents, we should find that at least three-fourths of that total length lay where the streams run against the dips.

It is clear, then, that the structural deformations of the region—the faults, flexures, and swells, had nothing to do with determining the present distribution of the drainage. The rivers are where they are in spite of them. As these irregularities rose up, the streams turned neither to the right nor to the left, but cut their way through them in the same old places. The process may be illustrated by a feeble analogy with the saw mill. The river is the saw, the strata are the timber which is fed against it. The saw-log moves while the saw vibrates in its place. The river holds its position almost as rigidly, and the rising strata are dissevered by its ceaseless wear.

What, then, determined the situation of the present drainage channels? The answer is that they were determined by the configuration of the old Eocene lake-bottom at the time the lake was drained. Then surely the watercourses ran in conformity with the surface of the uppermost Tertiary stratum. Soon afterwards that surface began to be deformed by unequal displacement, but the rivers had fastened themselves to their places and refused to be diverted. This, then, is the key which unlocks for the geologist the vestibule of the Plateau Country. The rivers were born with the country itself, they are older than its cliffs and cañons, older than its great erosion—the oldest things in its Tertiary history; nay, they are its history, which we may yet read imperfectly in their cañon walls. The mountains and plateaus are of subsequent origin. They arose athwart the streams only to be cleft asunder to give passage to the waters. The rivers amid all changes have ever successfully maintained their right of way. Such are the uses of the limited theorem of the persistence of rivers.[1] I shall not attempt to suggest how far it may be applicable to other regions, but I am confident that any geologist visiting the Plateau Country will be quickly overwhelmed with the conviction that it is true there.

In this connection it remains to add something to indicate the magnitude of the work accomplished, and the real extent of the obstacles which the Colorado has accomplished in maintaining its existence. In the Colorado itself, the maximum work has been done at the Grand Cañon (Fig. 2). This chasm is 217 miles in length, to which should be added properly the Marble Cañon above, 69 miles long, since the two are continuous, and their separation merely nominal. The average depth of the Grand Cañon is a little more than 5,200 feet—almost exactly one mile. Its maximum depth through the Kaibab Plateau is nearly 6,300 feet, this depth being maintained approximately as the river runs for about fifty miles. Surely it might be thought that to cut such an abyss is work enough in the life of one river however ancient of days. But the summit of the Kaibab is Carboniferous limestone. When the river began to run in this part the whole local Mesozoic and lower Eocene series rested upon the site of this plateau, but have since been swept away together with a part of the Carboniferous rocks. The river has cut through the entire fossiliferous system of strata and now runs 2,000 feet deep in the archæan. The total thickness of the fossiliferous system here is, or rather was, very nearly 17,000 feet. Hence in its lifetime the river has cut through about 19,000 feet of strata. Through the remainder of the Grand Cañon the total cutting has been from 2,000 to 3,000 feet less. As we ascend the river the amount diminishes—not regularly but with local maxima—until we approach the southern base of the Uintas. The principal branch, the Green River, has cut its channel into the quartzites of this range even more deeply than the Colorado in the Kaibab. Yet strangely enough the instant the Green is clear of the mountains it enters a long stretch where the cutting has been practically nothing. The explanation of this contrast will become obvious to the geologist by a mere reference to the fact that where the cutting has been zero the locality has been always at the base level of erosion, and never above it. Only those parts which rise above the base level are cut down.

(To be continued.)

[1] Mr. Jukes employed the same principle in explaining some features in the lower courses of the rivers of Ireland. *Quart. Journ.* Geol. Soc. of London, xviii. (1862), 378, quoted in Jukes and Geikie's "Manual of Geology," Third Edition, p. 454. [But the idea may be found in Hutton's great work the "Theory of the Earth," and in Playfair's "Illustrations." See particularly pp. 102 and 350 *et seq.* of the latter work.—ED.]

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